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INTERCRYSTALLINE CORROSION OF ALUMINUM ALLOYS, II. Al-Zn-Mg

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[A Digest]

Alloys of this type have good mechanical properties and are superior to duraluminum in that respect. However, they exhibit intercrystalline cracking which, as shown by the example of brass, is not a phenomenon entirely limited to aluminum alloys. Upon artificial aging, duraluminum corrodes along the grain boundaries. Application of a tensile stress does not make the alloy sensitive to corrosion cracking, but only promotes corrosion to an insignificant degree. On the other hand, an alloy of the type Al-Zn-Mg does not show intercrystalline corrosion, while a tensile strain brings about corrosion cracking. Althof (3) ascribes corrosion under stress primarily to the separation of intermetallic compounds along the grain boundaries and the creation of tensile strain. In the case of duraluminum, corrosion takes place in the absence of an applied stress, because the alloy is in an "active state," while alloys which corrode only under strain become active as a result of the application of stress. Thus, highly dispersed intercrystalline deposits on the grain boundary usually occur in alloys which are sensitive to corrosion under stress.

It has been established, up to the date of the present investigation, that the best mechanical properties are shown by alloys in which the intermetallic compound $MgZn_2$ serves as the hardening phase. The destruction of this compound brings about corrosion cracking. Similarly, intercrystalline corrosion of duraluminum is caused by the destruction of deposited $CuAl_2$ rather than the "active state" assumed by Althof.

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To clarify the conditions which underlie the corrosion of $MgZn_2$, the experimental method of continuous polishing in a corroding solution was chosen (6). Polishing changes the electrode potential of $MgZn_2$ by 567 mV in 3-percent NaCl as compared with 68 mV for pure Mg or Zn. This increase of potential can be explained as follows. The surface of the alloy after it has been exposed to the solution probably consists of atoms of zinc only; the magnesium has been dissolved from the surface. Polishing exposes the magnesium. This dissolves rather rapidly in contact with zinc, because micro-couples are formed. More magnesium than zinc goes into solution in the initial stage of the experiment, as shown by analytical data.

Further insight into the process of corrosion studied here could be gained by measuring the current strength produced by the couples $MgZn_2$/Mg (I), Zn/Mg (II), and Mg_3Zn_2/Zn (III) in 3-percent NaCl and plotting the current strength against time. I gave 5mA, first falling, then remaining constant at the level of approximately 3mA for 20 hours, then rising again. II, starting at 7mA, dropped in 15 minutes to 0.8mA due to polarization and remained on that low level. III, initially 4.5mA, dropped in 5 minutes to -0.1mA, the constant value retained during the rest of the time of the experiment (40 hours). To understand this series of results, one must bear in mind that the hydrogen overvoltage is much lower on the zinc in I than on the pure rolled zinc electrode in II. Another explanation of the high current with I would be the greatly increased surface of the zinc formed from $MgZn_2$.

In another series of experiments the corrosion resistance of $MgZn_2$, short-circuited Mg/Zn, and a Mg/Zn pair lacking direct contact is compared. The results are shown in the drawing /appended/, from which the inhibiting action of Zn in $MgZn_2$ (in the absence of polishing) is apparent. The corresponding results for $CuAl_2$ (obtained in earlier experiments) are also shown. The essential difference in the behavior of the two intermetallic compounds can be seen clearly from the drawing.

If $MgZn_2$ corrodes less readily than $CuAl_2$, why should Al-Zn-Mg be especially sensitive to corrosion in the presence of tensile strain? Apparently the crystal lattice of $MgZn_2$ is particularly easily distorted by a mechanical stress, so that the magnesium becomes susceptible to electrochemical action. In the process of corrosion, the zinc acts as a cathode and the aluminum, which is a particularly weak cathode, does not have much influence on the process. Heat treatment, mechanical working, and addition of other elements will break up the continuity of the intercrystalline deposit between the grains and thereby reduce corrosion.

Corrosion of intermetallic compounds ($MgZn_2$, $CuAl_2$ and Al_3Mg_4 in the case of electron metal) has a dominant effect in intercrystalline corrosion and corrosion cracking.

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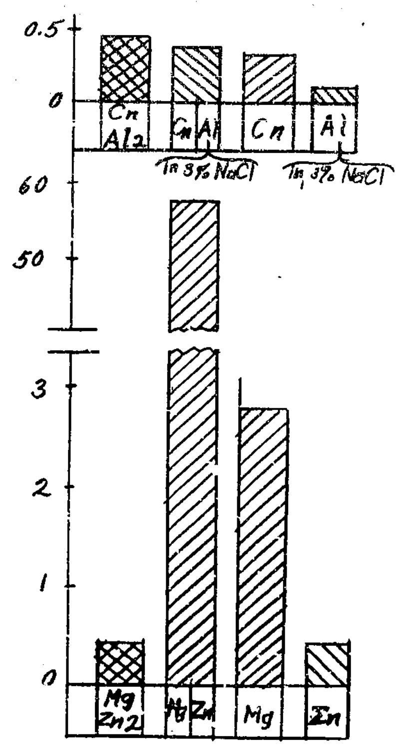
[Figure follows]



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